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## A PRELIMINARY METEOROLOGICAL SURVEY FOR AIRSHIP BASES ON THE MIDDLE ATLANTIC SEABOARD


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Location of a base for an airship terminal is analogous to the selection of proper docking facilities for ocean-going vessels. In addition to the usual docks required at any location, a natural harbor is always selected. These harbors, provided by nature, are visible, tangible things whose suitability may be quickly judged. In the case of aircraft, we maintain that there exist similar natural air harbors, however invisible and intangible. By meteorological and climatological analyses the location of these natural air harbors may be ascertained.

For a preliminary and general survey of the Atlantic coastal plain, we were fortunate in having the cooperation of the United States Weather Bureau and the Meteorological Services of the Army and the Navy. It is the purpose of this preliminary study to coordinate the data furnished by the above mentioned services in such a form as to isolate in a general way the desirable area from the undesirable on the middle Atlantic seaboard. Further examination is being made of wind conditions on possible sites in the area found generally favorable.

In a letter of May 8, 1930, the United States Weather Bureau issued detailed instructions for the compilation of the fundamental records used in this study. With the exception of the precipitation, temperature, and thunderstorm data, taken from the Atlas of American Agriculture, all data used in the study originated from the instructions of this letter.

In the selection of an airship base it is obvious that certain weather characteristics must have an important bearing. In this study particular emphasis has been placed on the following characteristics: Fog, snow, rain, thunderstorms, temperature, and winds. These factors influence the buoyancy of the ship, the ease of operation in flight, and handling on the ground.

Data pertinent to our conclusions are presented in complete detail in Appendix A of this report, copies of which are on file at the offices of the International Zeppelin Transport Corporation; the Pacific Zeppelin Transport Co. (Ltd.), in New York City; the Goodyear Zeppelin Corporation at Akron, Ohio; the United States Weather Bureau; the Aerological Office; United States Naval Air Station, Lakehurst, N. J.; and the offices of the heads of the Army and Navy Meteorological Services at Washington, D. C.

The following charts are taken from the above-mentioned Appendix A and are indicative of conditions exhibited by other charts in the same study, and presented as representative charts applicable to this study.

The following paragraphs discuss briefly weather conditions affecting the desirability of areas under consideration for airship bases.

*Temperatures.*—The lifting characteristics of airships are dependent on temperature. With increased temperature in the summer time, the outside air density decreases and the ship loses in lift for a given volume. Low temperatures are to be avoided in the winter months even though they are productive of increased lifting power of the airship, for the reason that low temperatures are frequently accompanied by snow and glaze storms. In addition, labor necessary for the maintenance of airships becomes inefficient at low temperatures. The lines on Chart 6 show the average daily temperature in summer. It will be noted that an increase in temperature occurs to the south of Washington. Due to the resulting loss of buoyancy in the summer time, the area to the north of Washington or perhaps Richmond would be desirable. For winter operating conditions (charts for which closely parallel Chart 6, but with an approximate reduction of 40°) the desirable area would be south of the line between Trenton and Harrisburg.

*Temperature range.*—Fluctuations in temperature cause the lifting gas of an airship to expand and contract. The maximum volume of an airship, of course, is fixed, and the lifting power is, therefore, limited by the maximum temperature. Large fluctuations in temperatures exercise a harmful influence on buoyancy and economy of operation; therefore, small fluctuations of temperature are desirable at an airship terminal. Such fluctuations in temperature are shown on Chart 8 for the summer months, exhibiting a maximum fluctuation in southwestern Pennsylvania. From this chart the desirability of close proximity to the seacoast is apparent. However, it will be shown later that wind conditions do not permit such close proximity to the coast, and, therefore, the desirable area should probably include Philadelphia, Baltimore, and Richmond. For daily fluctuations of temperature in the winter, Chart 9 is presented. Here again the desirability of staying close to the Atlantic seaboard is apparent, and also it is possible to obtain a very small fluctuation of temperature in the vicinity of Philadelphia, Baltimore, and Richmond. The stabilizing influence of the Atlantic Ocean is apparent on both charts.

*Thunderstorms.*—It is popularly believed that the hazards to aircraft from thunderstorms are dependent entirely on lightning. Recently, studies and flight experience indicate that the real hazards of flying in the vicinity of thunderstorms are the tubulence or whirlpools in the air and the squalls which accompany such phenomena. The desirability of avoiding such storms is apparent. For the study of thunderstorms the number of days per year with such storms is presented on Chart 10. It will be noted that a fairly constant increase in the number of thunderstorms per year occurs from Trenton southwest to the Gulf States, where a maximum occurs. A reasonable area from a thunderstorm viewpoint is the Trenton Richmond area, in which 32 to 40 thunderstorms occur per annum.

*Snow.*—Snow influences the operation of an aircraft in two respects. On an airship moored to a mast the snow has a tendency to accumulate on the upper surface and add appreciable weight to the ship. This can be avoided by the use of ballast which is an inconvenience. In flight, the snow is blown off of the surface of the ship, and the only detrimental effect encountered is impaired visibility. It is anticipated, with recent improvements in mechanical handling of airships on the ground, that the ill effects of snow on the ground will be largely eliminated. Chart 11 shows the distribution of days per year with snow cover on the ground. It will be noted a marked decrease in the number of days per year with snow occurs southward and southwesterly from Philadelphia. More desirable conditions are apparent at Richmond.

*Rain.*—Rain has somewhat the same influence on the operation of an airship as snow. Considerable weight may be added to the craft when moored to a mast, or weight may be added in flight by a heavy shower. Impaired visibility, of course, accompanies rainfall. Chart 14 shows the number of days per year with rainfall and on this chart the entire middle Atlantic seaboard may be considered satisfactory.

For maximum rainfall in any 24-hour period, Chart 16 has been constructed. Here it is obvious that the most desirable location should be an appreciable distance from the seaboard, preferably 50 to 100 miles.

*Fog.*—In the study of fog, Chart 13 represents the average number of days per year with dense fog. On the chart, the optimum area is inclosed, showing Richmond, Washington, and Philadelphia to be satisfactory. Baltimore is a trifle high, but not seriously so. As is to be expected, the coastal stations of New York, Atlantic City, and Cape Henry are poor.

*Docking.*—The docking of an airship consists of transferring the ship from its location on the field into the hangar or dock. This operation is usually carried out in favorable wind conditions. It is apparent that a strong cross-hangar wind is productive of severe strains on the airship and some hazard of damage is present. Therefore, favorable wind conditions for docking can be judged by the occurrence of the lower wind speeds.

When the wind velocities are 5 miles per hour or under for one hour or more in 24, this condition is tabulated as a docking day. The average docking days per year are plotted on Chart 18 and the desirable area is inclosed. In the chart some consideration should be given to interpreting the values for Philadelphia and Trenton which were derived from the anemometer exposures of 190 and 180 feet, respectively. These high exposures are productive of higher wind velocity records than are representative for these locations. The optimum area includes Baltimore and Washington, and is very close to Richmond.

*"No ground handling."*—At higher wind velocities the handling of an airship in close proximity to the ground is somewhat difficult. This may be due to fluctuations in wind speed or turbulence produced by the air flow. The combination of wind fluctuations and the higher force of the strong wind itself can make the handling of an airship on the ground impractical. Such conditions are here described as "No ground handling" conditions. Chart 28 shows as "no ground handling" days, the times per year when winds of 13 miles per hour or over are encountered for the entire 24 hours. The optimum area in this case includes the Baltimore and Washington section.

*Mooring delays.*—Mooring of an airship consists of anchoring the ship to a high or stub mast by means of cables. This operation is possible in winds of higher velocities, but delay may be encountered when wind velocities of 30 miles or more are encountered.

Mooring delays per year are shown on Chart 34. When winds of 30 miles per hour or more are encountered for a period of 6 to 11 hours, that period is tabulated as a mooring delay. Attention is invited to the shape of the inclosed desirable area which closely approximates the shape of the inclosures of many of the wind charts exhibited in Appendix A. The desirable area includes Philadelphia, Baltimore, Washington, Richmond, and extends on southwesterly. Poor conditions are exhibited at coastal locations.

*Distribution of wind velocities.*—For another method of studying wind velocities, we have divided the velocities into the following limits: 0 to 5, 6 to 12, 13 to 20, and 21 or more miles per hour. The total number of hours which the wind blew within these velocity limits was used as a basis of this study. For the most desirable conditions we should look for a maximum number of hours for which the wind blew within velocity limits of 0 to 5 miles per hour, and conversely, a minimum number of hours for velocities of 6 or more miles per hour.

Chart 43 shows the total number of hours per year, averaged from 5-year data, that the wind blew within velocity limits of 0 to 5 miles per hour. The inclosed optimum area extends northward nearly to Philadelphia. There may be some question as to Hadley Field being included in the desirable area due to the break in conditions exhibited in the vicinity of Philadelphia. No accurate method was available to justify the exclusion of this station, and it was therefore included.

For velocity limits of 6 to 12 miles per hour, wind conditions are shown on Chart 44 giving total hours per year for this velocity limit. The inclosed optimum area has the usual characteristic shape with the exception that it includes Mitchell and Hadley Fields usually excluded on other charts.

Velocity limits of 13 to 20 miles per hour are shown on Chart 45. The shape of the optimum area is of the usual type with the exception that it includes Hadley Field in the area.

For velocity limits of 21 or more miles per hour, the hours per year are shown on Chart 46, showing the characteristic shape of the desirable area which includes Philadelphia, Baltimore, Washington, and Richmond.

*Hangar orientation.*—For study of wind direction applicable to hangar orientation the polar coordinate charts, Nos. 64 and 65, are incorporated as representing typical direction studies. It will be noticed on Chart 64, the days and nights with low winds of 0 to 5 miles per hour were excluded and the chart covered only those periods in which winds of 6 to 12 miles per hour were encountered for one or more hours. Some question may be raised as to the desirability of excluding those periods in which docking conditions of 0 to 5 miles per hour exist, but it was felt that the inclusion of those periods would merely mean the addition of a constant value to the radii of Chart 64. The prevailing wind direction is shown as a maximum westerly direction on this chart.

On Chart 65 the distribution of wind directions and velocities is shown by various limits of 6 to 12, 13 to 20, and 21 or more miles per hour. The wind direction on the chart is somewhat variable, but quite desirable from a velocity viewpoint, showing predominance of winds of low velocities and low frequency of winds of a higher velocity.

SUMMARY

For a summation of the precipitation, fog, thunderstorm, and temperature conditions Chart 1 was devised. This chart represents a composite of *all* conditions other than wind, taken from Appendix A and superimposed upon each other to obtain the most desirable or optimum area. The shaded area in the chart represents the optimum area and includes Philadelphia and Washington. The isogram to the west of Washington is a temperature line, and therefore may be considered somewhat flexible, sufficiently so to justify the inclusion of Washington and perhaps Richmond in this area. Baltimore is slightly below normal on fog conditions. Richmond has slightly more thunderstorms and slightly higher summer temperatures but should be included in the desirable area.

Chart 2 represents a composite summary of all wind conditions described in Appendix A. The optimum area is shaded in this chart and lies slightly to the westward of Philadelphia and to the north of Richmond. Only one or two lines exclude Richmond and Washington from the optimum area, and therefore they should be included in that area. There is an apparent transition in the weather conditions in the vicinity of Philadelphia, becoming increasingly poor to the northeast. Therefore, as a northern limit to the desirable area, Philadelphia is included. Comparatively few lines exclude Richmond, which is likewise recommended for the desirable area.

Anticipating the development of mechanical handling of airships in higher wind velocities than has been common in the past, we have provided in Chart 3 a summary of all wind conditions and velocities of 21 miles per hour or more. This composite chart was likewise obtained from superimposing all wind charts above 21 miles per hour shown in Appendix A of this study and the optimum area is shown in the shaded portions. Philadelphia represents the northeastern limit of this area which also includes Baltimore. Richmond is excluded by a single line and Washington is in close proximity to the desirable area and these cities are, therefore, recommended to be included in the optimum area.

COMPARISON OF STUDY AND INDEPENDENT STUDIES

In order to align this study with similar efforts we have provided Chart 4, comparing the centers of the desirable areas with the average wind velocities. The lines for average wind velocities are taken directly from the Atlas of American Agriculture, Part 2, Section B, by J. B. Kincer. This phase of the chart was based on anemometer records of the 20-year period from 1891 to 1910, inclusive, taken at 175 Weather Bureau stations scattered throughout the United States. Corrections were applied for the heights of the anemometers to estimate the wind that would have occurred at the uniform elevation of 100 feet above the ground. It will be noted that a marked increase in velocity occurs from the Atlantic seaboard to the west and that the desirable area based on average wind velocity conditions alone would include Washington, Philadelphia, Baltimore, and Richmond. Low temperatures and snow would limit the northern extent of the area to Philadelphia, while the southern cut-off would occur south of Richmond due to high temperatures and thunderstorms.

To compare the average velocity features of Chart 4 with our study, a line in the center of the optimum area of each chart was drawn to represent the locus of maximum desirability. All charts in Appendix A, including the climatological and wind charts, were thus treated and superimposed on the average wind velocities of Chart 4. Obviously the location where the lines are the densest may be considered the optimum area. It is a striking feature of this comparison that the loci of the optimum points coincide with the desirable area as indicated by the average wind velocities. It is certainly to be expected that the various methods should be in reasonable agreement but in this case the conclusions are identical.

CONCLUSIONS

In Appendix A the statement is made that an examination of the study will show the desirability of keeping at least 30 miles back from the shore line of the Atlantic seaboard. This statement was based largely on summaries shown on Charts 2 and 3 showing the eastern edge of the optimum area to have a very definite relation to the Atlantic coast. However, if we wish to secure the most perfect conditions possible near the eastern seaboard, it would appear that, based on the evidence on Chart 4, the airship base should be about 100 miles from the Atlantic coast. This statement is in agreement with our present conception of the influence of large bodies of water. We know definitely from temperature studies, free balloon flights, and similar phenomena that the direct influence of the sea breezes extends at least 30 miles inland. Further, it is also reasonable, as indicated by this study, that the complete dampening influence of the surface friction of the land area is not fully effective until a distance of about 100 miles from the Atlantic seaboard has been reached.

It should not be inferred that ideal conditions will be encountered 100 per cent of the time in any section of the middle Atlantic seaboard. However, from the data herein presented, it will be seen that in the desirable areas outlined in this study, the best attainable conditions will be encountered. By using the weather conditions encountered at the Naval Air Station at Lakehurst, N. J., as a standard of comparison, it is apparent that the operating conditions to be encountered at the proposed locations of Richmond, Washington, Baltimore, and Philadelphia will be very much better than those of Lakehurst.

In conformity with the conclusions of this study and Appendix A, we recommend that the locations of Richmond, Washington, and Baltimore be considered for a trans-Atlantic airship base, and also that Philadelphia be included as representing the most northerly point that we can conscientiously recommend for consideration. On these four locations anemometers have been erected and continuous records are being taken of wind velocity and direction characteristics, and the final selection of an airship base will be made largely from records thus obtained. Such records are necessarily affected largely by local topography which influence may modify the general views developed from the preliminary and general survey made in this report. It is only to be expected that in the large area here found to be generally favorable there may be locations that are more favored by nature than others.

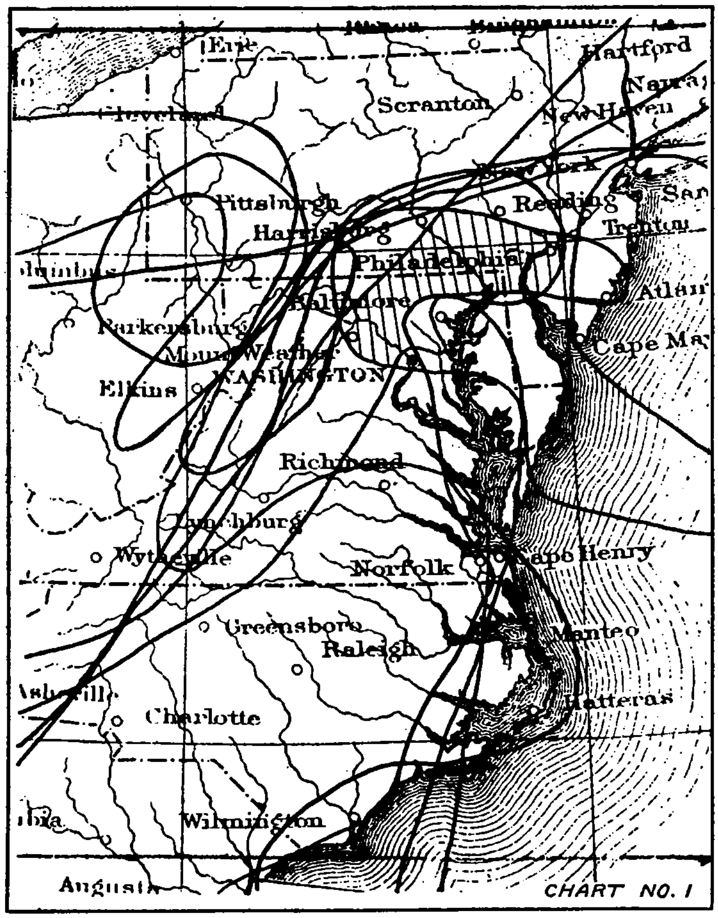



FIGURE 1 (CHART 1).—Summary of precipitation, fog, clouds, thunderstorms, and temperatures

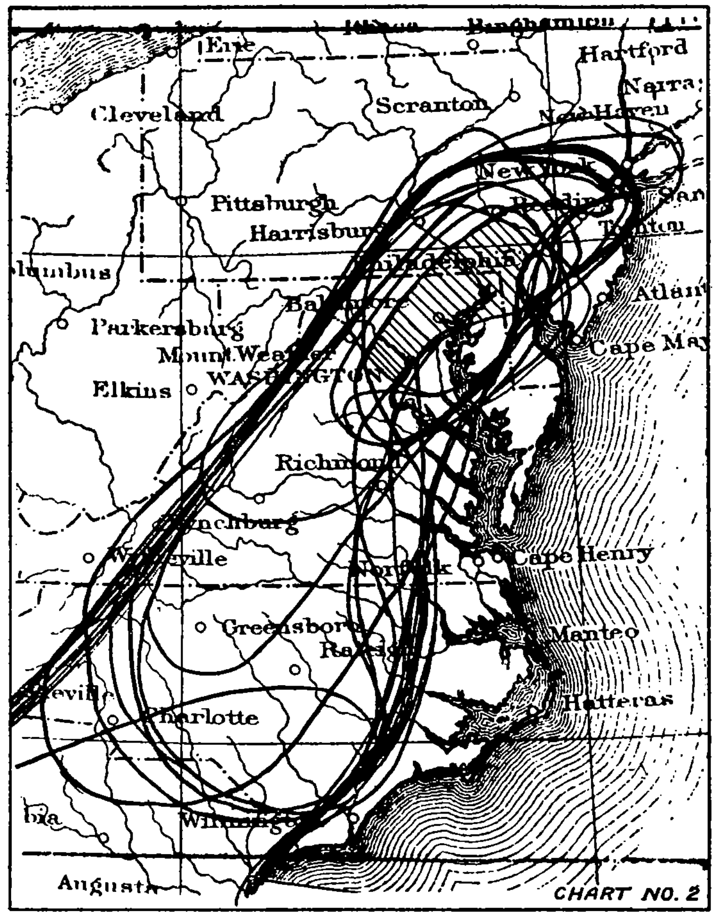



FIGURE 2 (CHART 2).—Summary of all wind conditions, shaded area most desirable

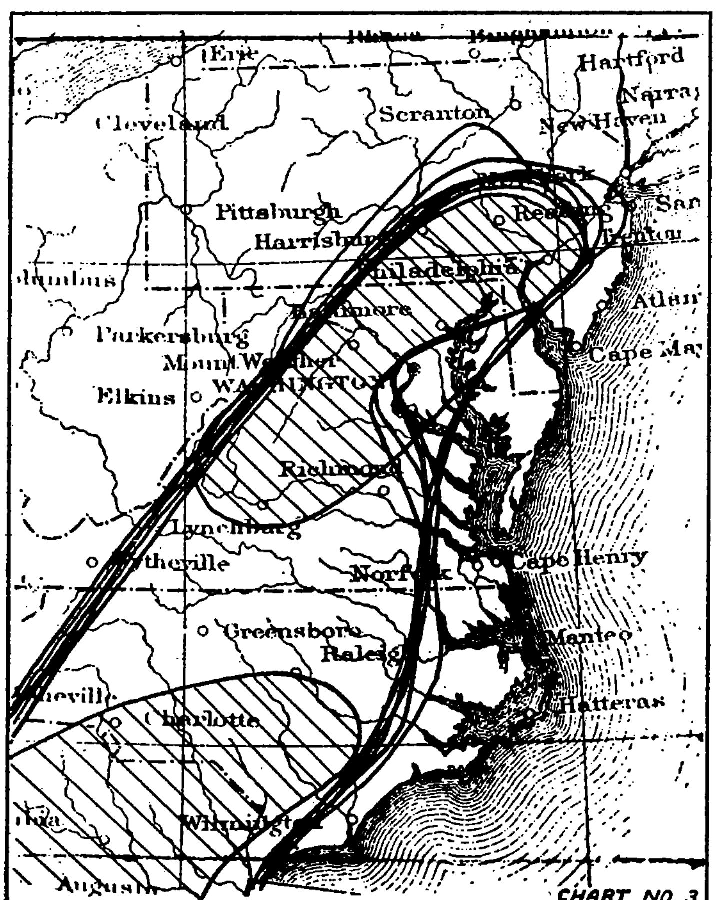



FIGURE 3 (CHART 3).—Summary of winds of 21 or more miles per hour

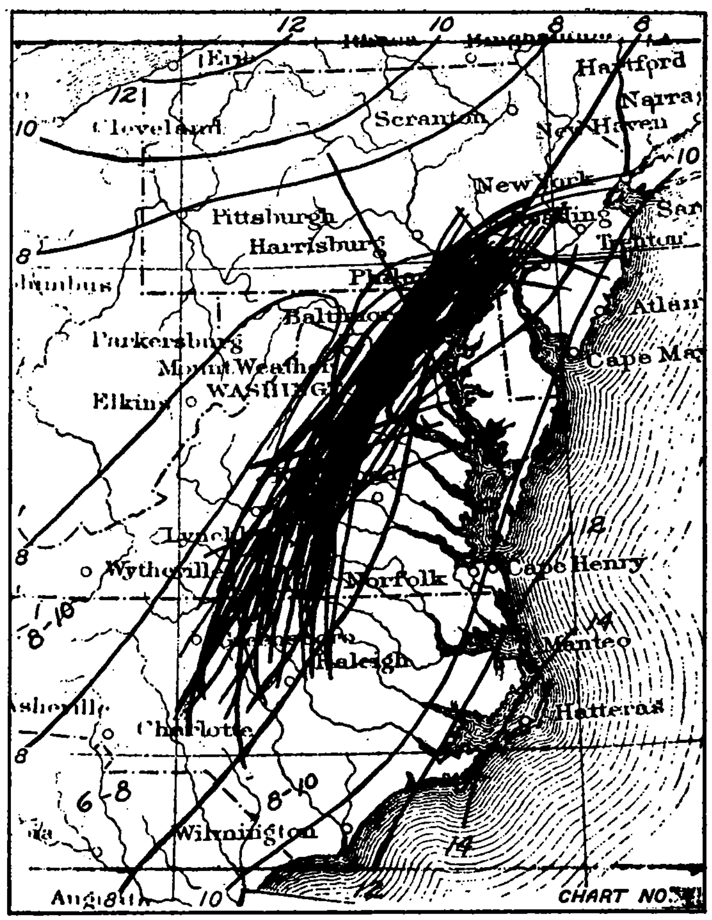



FIGURE 4 (CHART 4).—Centers of optimum areas compared to average wind velocities in miles per hour

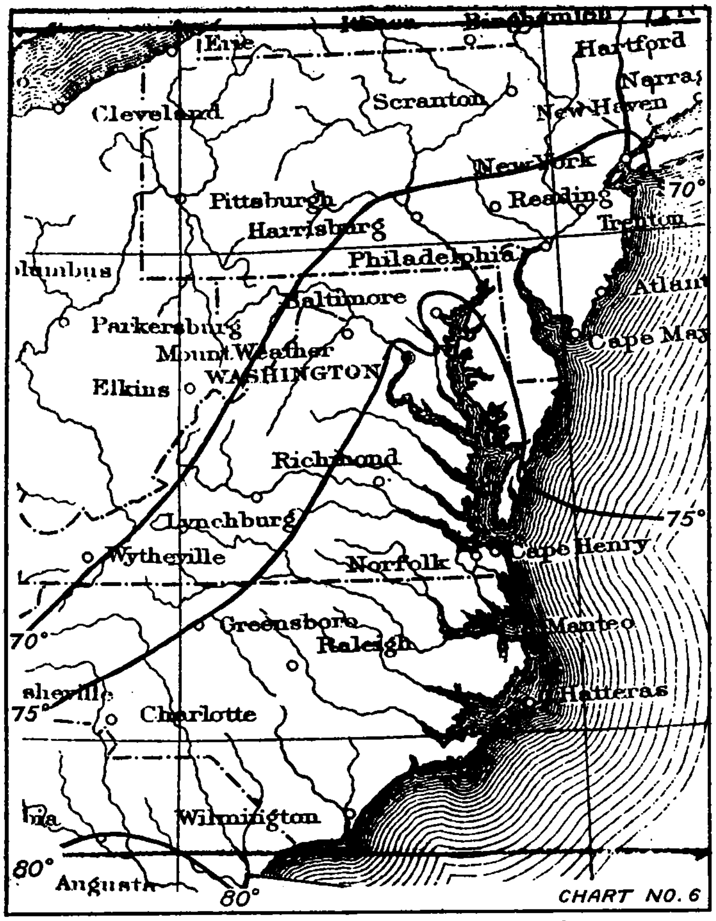



FIGURE 5 (CHART 6).—Average summer temperature, June, July, and August, 1895–1914

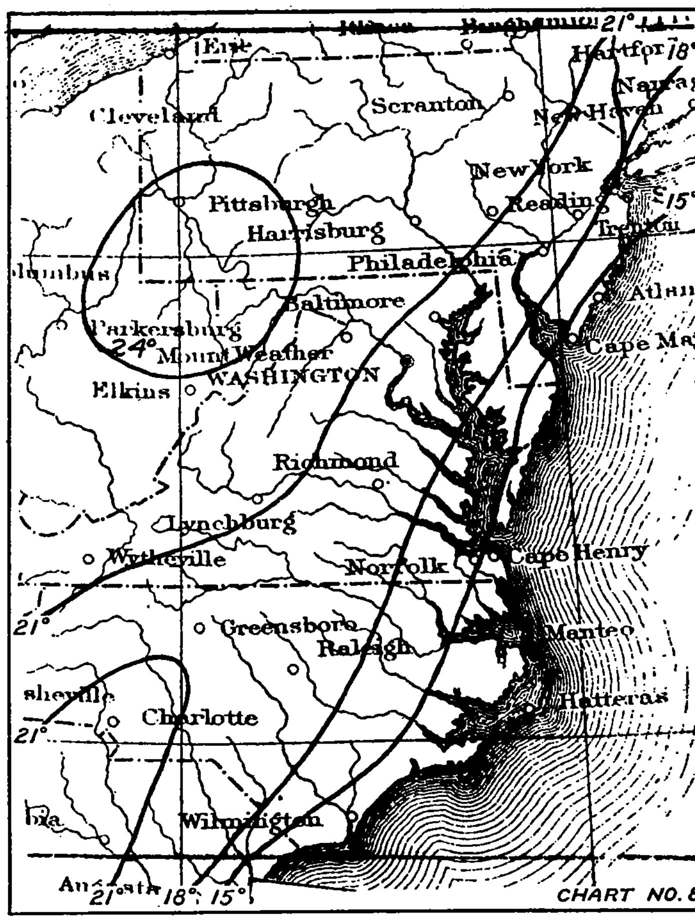



FIGURE 6 (CHART 8).—Average daily temperature range, July, 1895–1914

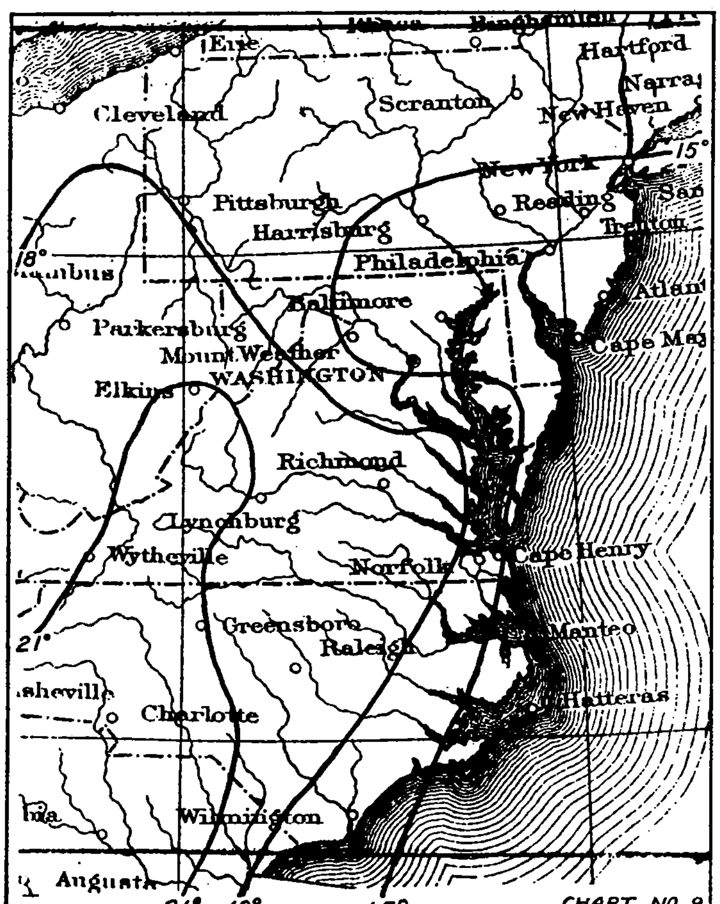



FIGURE 7 (CHART 9).—Average daily temperature range, January, 1895–1914

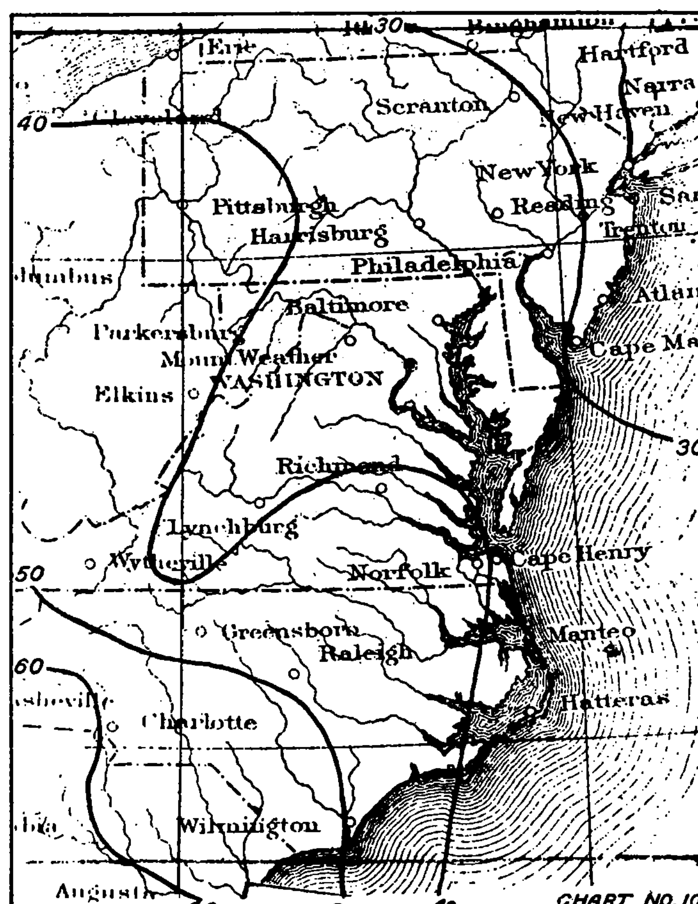



FIGURE 8 (CHART 10).—Average number of days with thunderstorms per year, 1904–1913

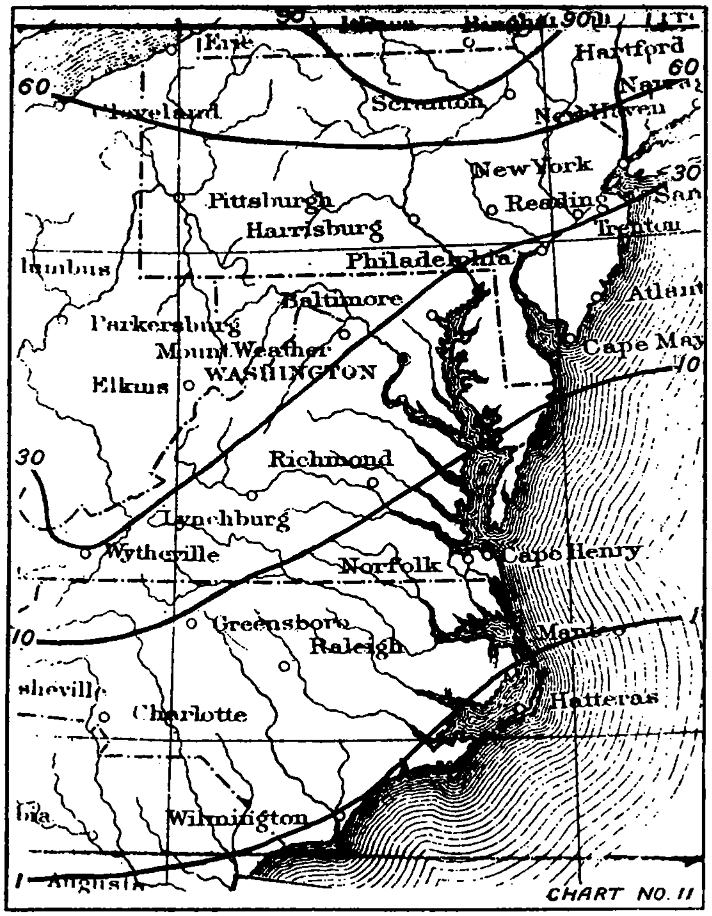



FIGURE 9 (CHART 11).—Average number of days with snow cover per year, 1895–1914

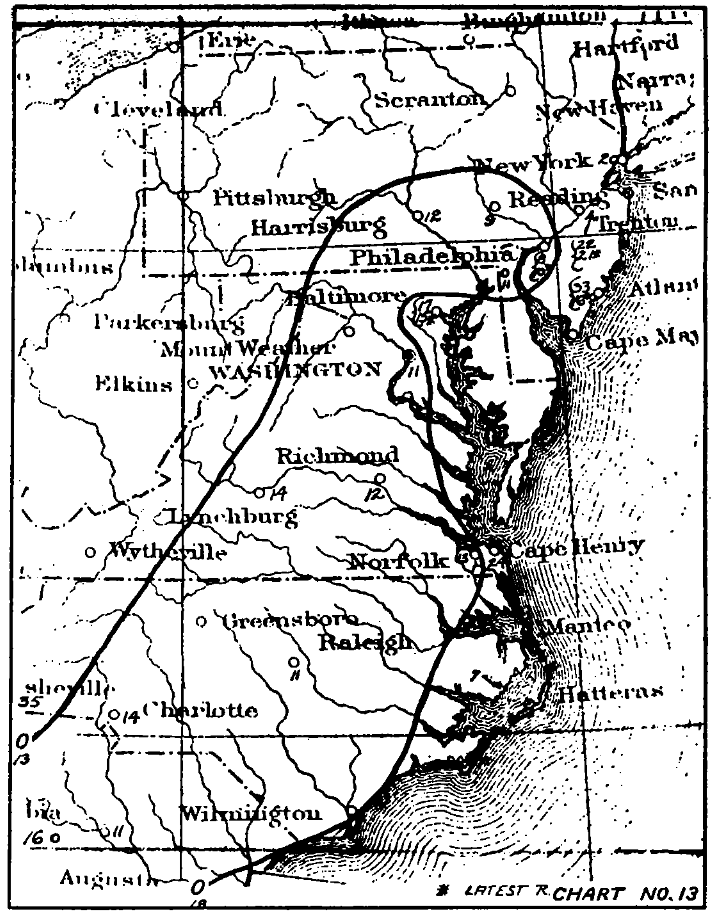



FIGURE 10 (CHART 13).—Average number of days with dense fog

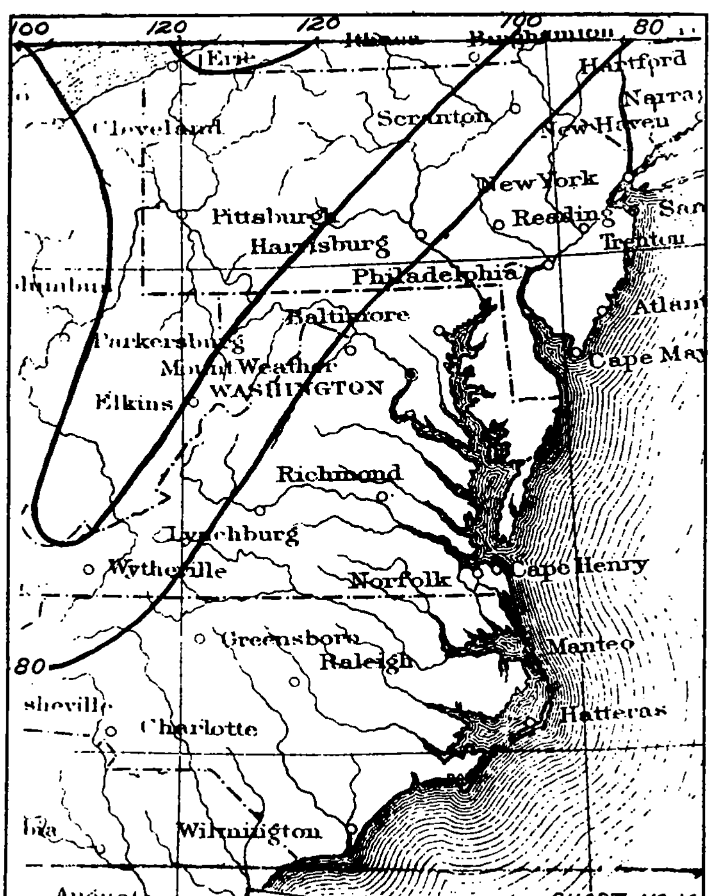



FIGURE 11 (CHART 14).—Average number of days with precipitation of 0.01 to 0.25 inch, 1895–1914

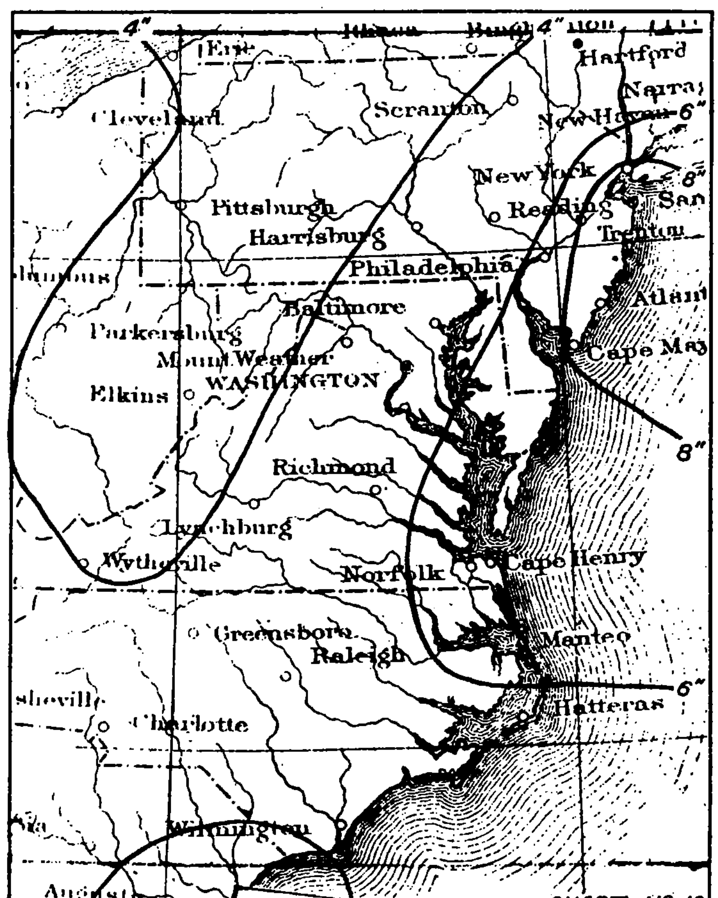



FIGURE 12 (CHART 16).—Maximum precipitation in 24 hours, 1895–1914

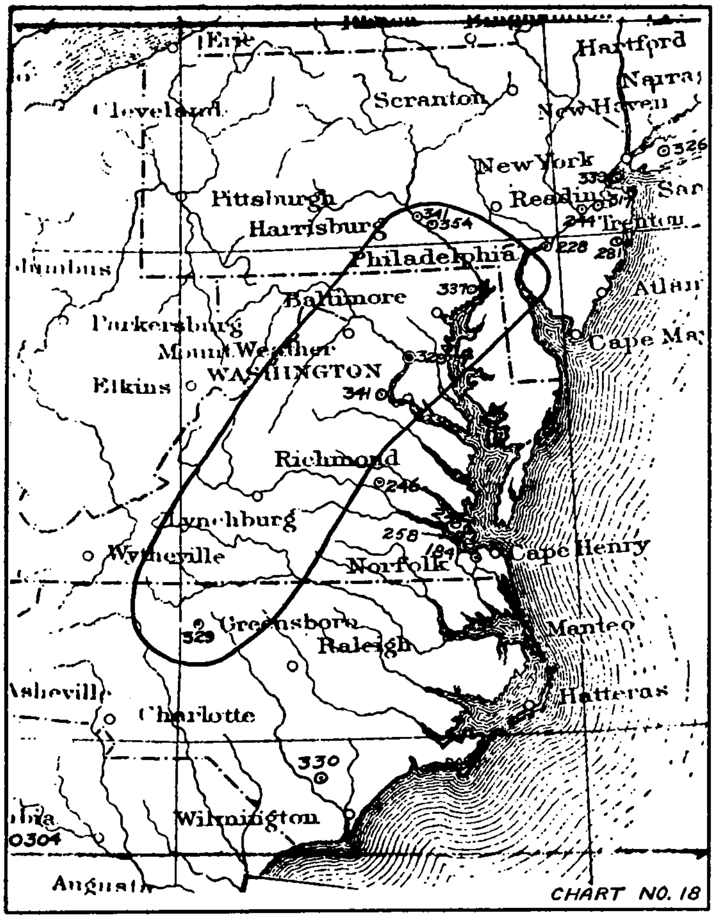



FIGURE 13 (CHART 18).—Docking days, 24 hours, winds of 5 miles per hour or under, for 1 hour or more

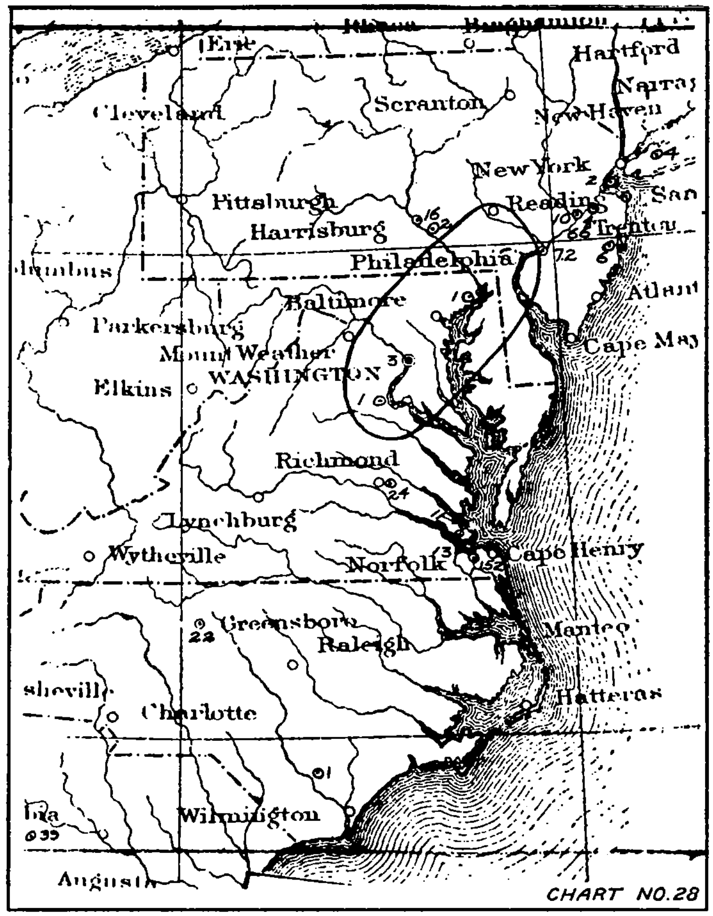



FIGURE 14 (CHART 28).—"No ground handling" days, winds of 13 miles per hour or over for entire 24 hours

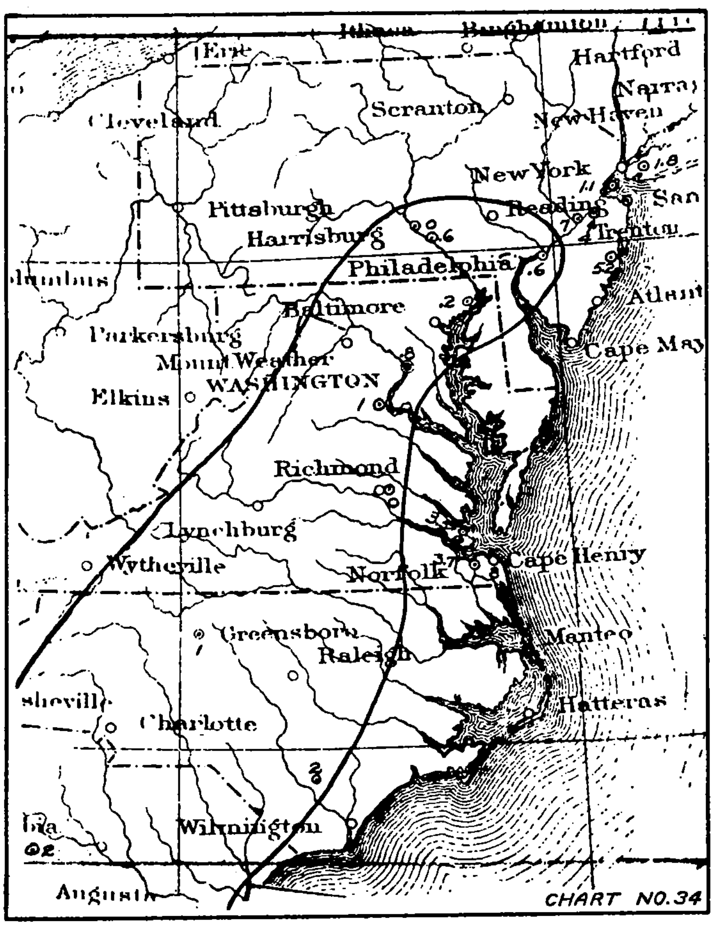



FIGURE 15 (CHART 34).—Mooring delays, winds of 30 miles per hour or more, periods of 6–11 hours

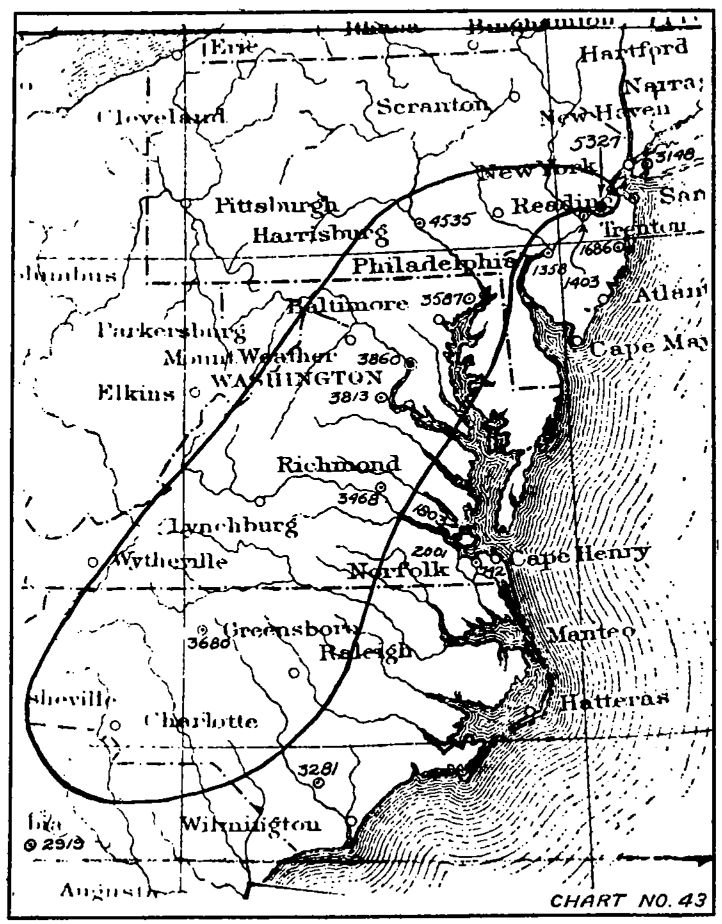



FIGURE 16 (CHART 43).—Hours per year, winds of 0–5 miles per hour

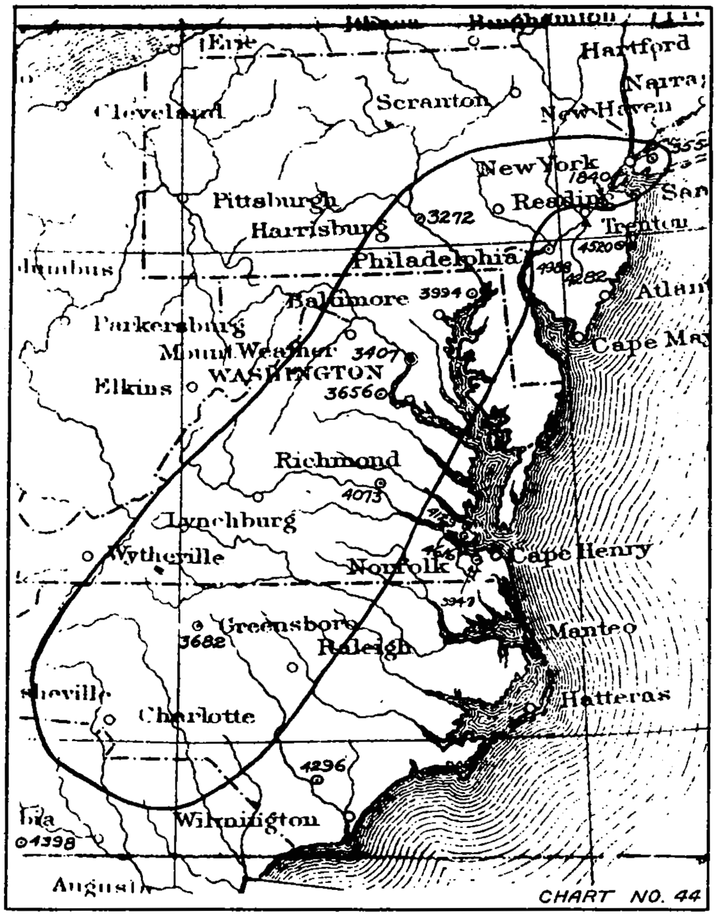



FIGURE 17 (CHART 44).—Hours per year, winds of 6–12 miles per hour

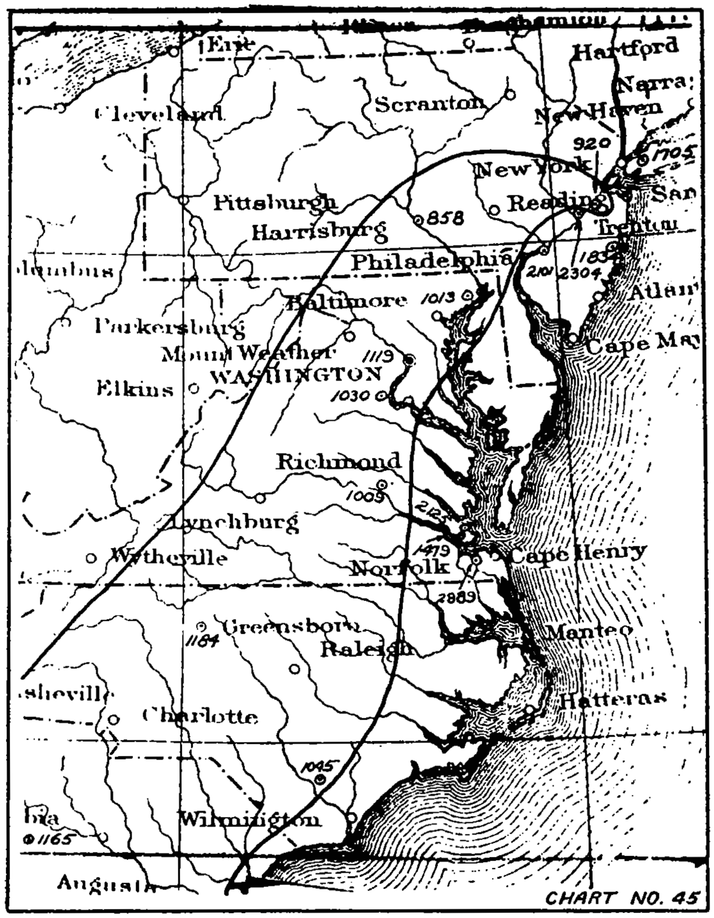



FIGURE 18 (CHART 45).—Hours per year, winds of 13–20 miles per hour

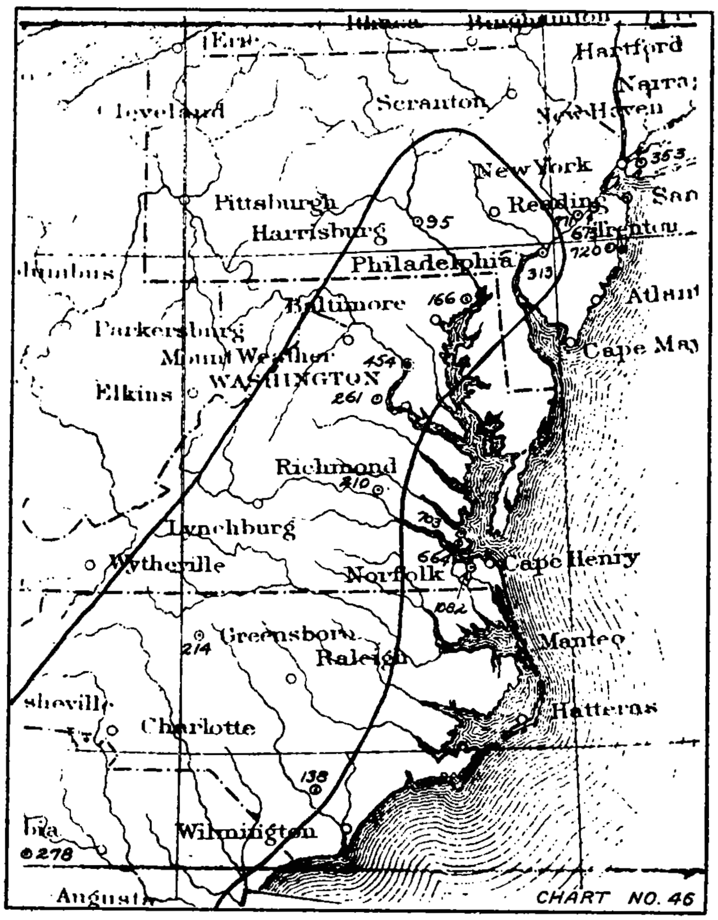



FIGURE 19 (CHART 46).—Hours per year, with winds of 21 miles per hour or more

(To face p. 64)

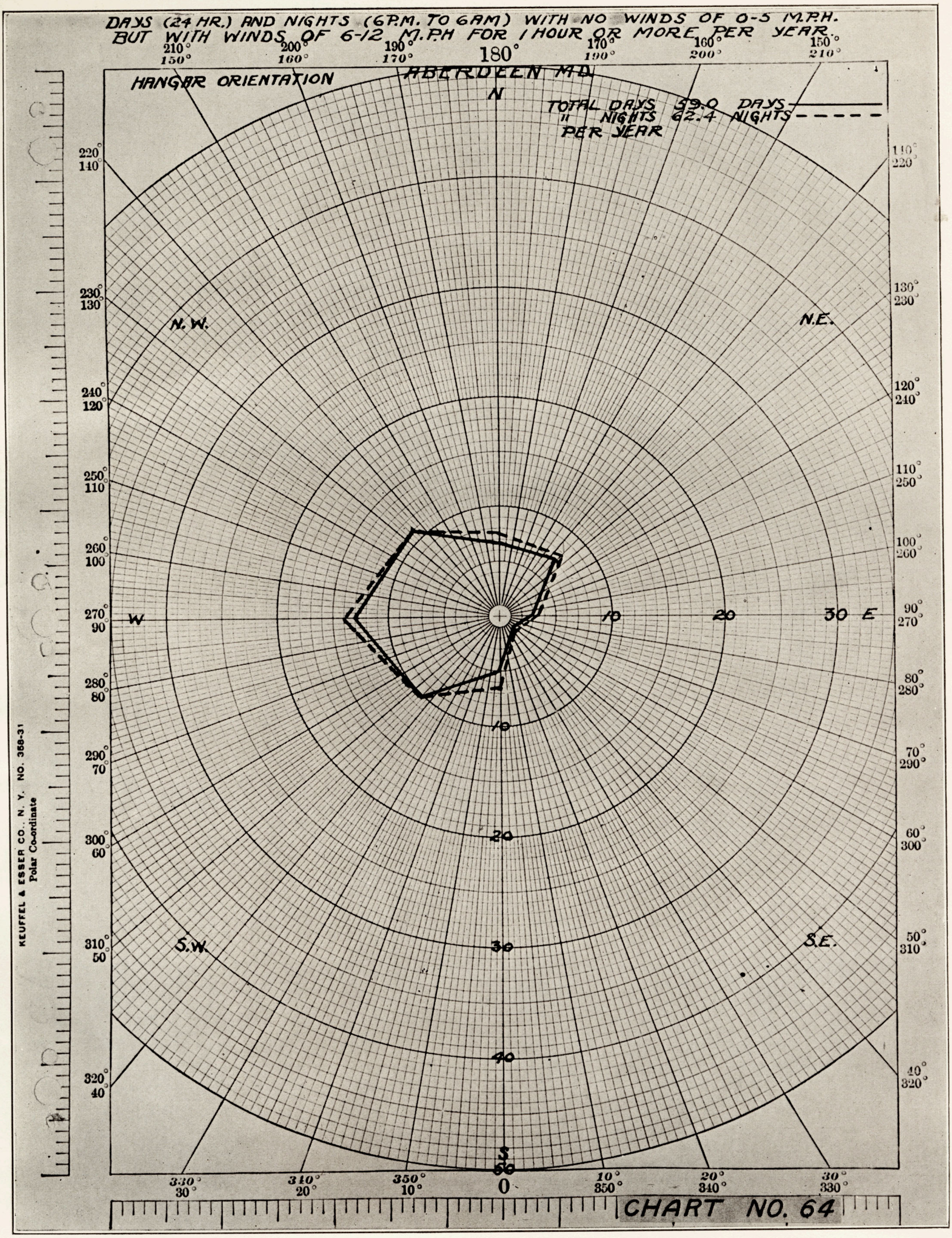
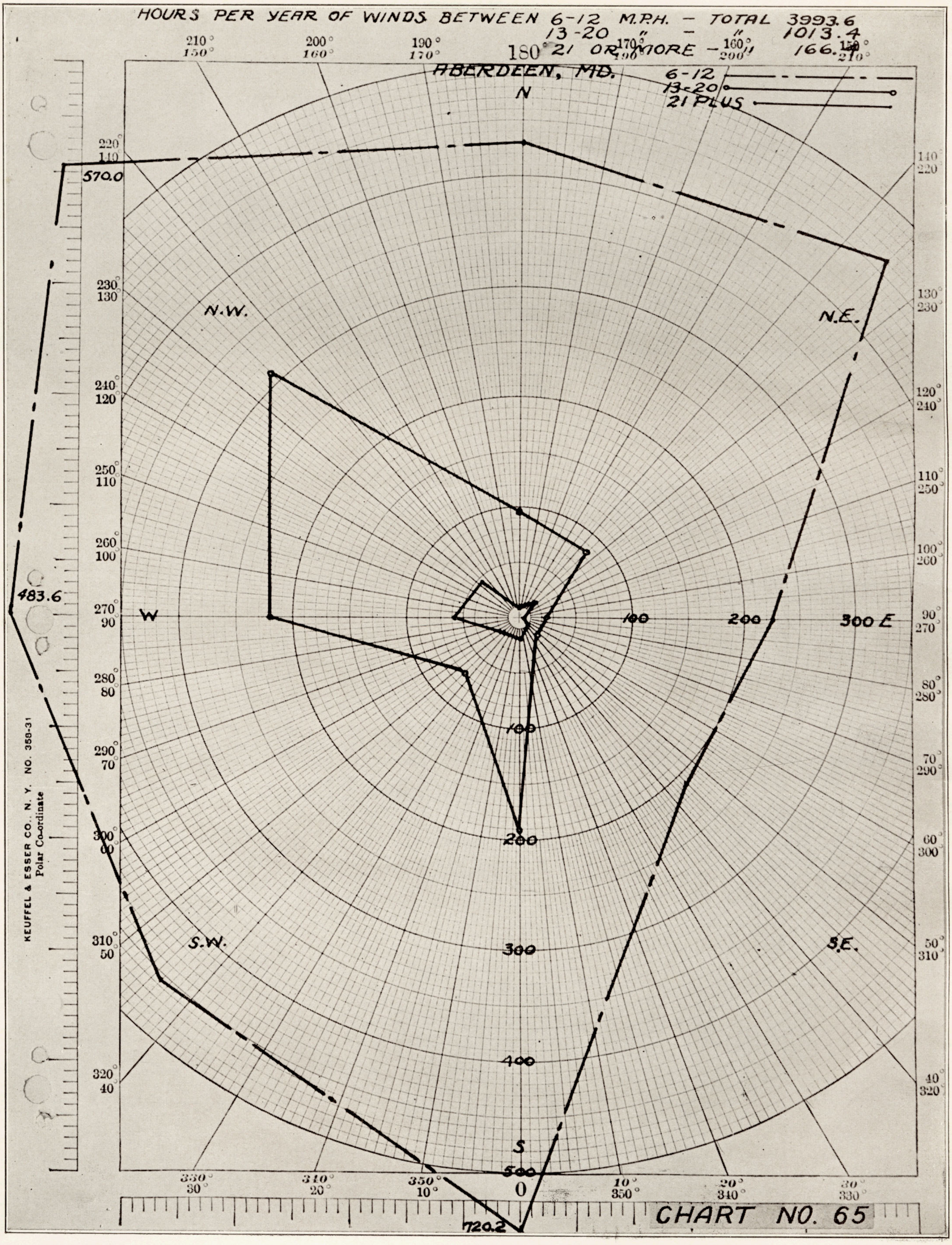



FIGURE 20


HOURS PER YEAR OF WINDS BETWEEN 6-12 M.P.H. - TOTAL 3993.6
13-20 " - " 1013.4
21 OR MORE - " 166.
ABERDEEN, MD.
6-12
13-20
21 PLUS
N
N.W.
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300 E
S.W.
S.E.
S
570.0
483.6
720.2
100
200
300
400
500
KEUFFEL & ESSER CO., N. Y. NO. 358-31
Polar Co-ordinate
CHART NO. 65

FIGURE 21